06EC756 -
Digital Image Processing

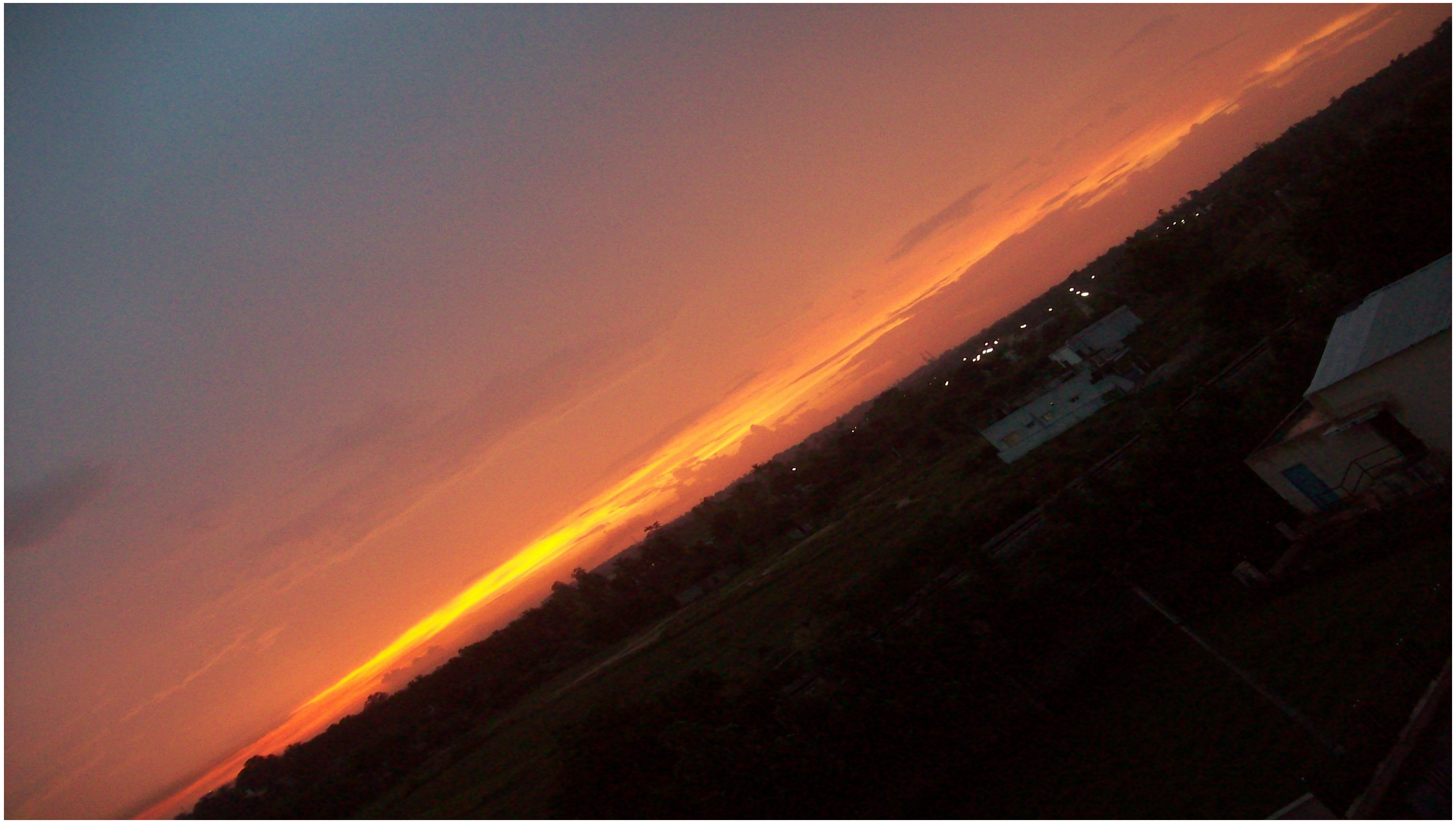

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Image Processing

Subject Code: **06EC756**	IA Marks : 25
No. of Lecture Hrs/Week : 04	Exam Hours : 03
Total no. of Lecture Hrs. : 52	Exam Marks : 100

Text Book:

1. "Digital Image Processing", Rafael C.Gonzalez and Richard E. Woods, Pearson Education, 2001, 2nd edition.

Reference Books:

"Fundamentals of Digital Image Processing", Anil K. Jain, Pearson Edun, 2001.
"Digital Image Processing and Analysis", B. Chanda and D. Dutta Majumdar, PHI, 2003.

PART - A

Unit - 1

Digital Image Fundamentals: What is Digital Image Processing. fundamental Steps in Digital Image Processing, Components of an Image processing system, elements of Visual Perception **6 Hours**

Unit - 2

Image Sensing and Acquisition, Image Sampling and Quantization, Some Basic Relationships between Pixels, Linear and Nonlinear Operations. **6 Hours**

Unit - 3

Image Transforms: Two-dimensional orthogonal & unitary transforms, properties of unitary transforms, two dimensional discrete Fourier transform. **6 Hours**

Unit - 4

Discrete cosine transform, sine transform, Hadamard transform, Haar transform, Slant transform, KL transform

6 Hours

PART - B

Unit - 5

Image Enhancement: Image Enhancement in Spatial domain, Some Basic Gray Level Trans -formations, Histogram Processing, Enhancement Using Arithmetic/Logic Operations. **6 Hours**

Unit - 6

Basics of Spatial Filtering Image enhancement in the Frequency Domain filters, Smoothing Frequency Domain filters, Sharpening Frequency Domain filters, homomorphic filtering. **6 Hours**

Unit - 7

Model of image degradation/restoration process, noise models, Restoration in the Presence of Noise, Only-Spatial Filtering Periodic Noise Reduction by Frequency Domain Filtering, Linear Position-Invariant Degradations, inverse filtering, minimum mean square error (Weiner) Filtering **10 Hours**

Unit - 8

Color Fundamentals. Color Models, Pseudo color Image Processing., processing basics of full color image processing

6 Hours

Unit1 : Contents

- Introduction: What is Digital Image Processing ?
- Fundamental steps in Digital Image Processing
- Components of an Image processing system
- Elements of Visual Perception

Objectives

- Define the scope of Image Processing
- Principal areas of application
- Principal approaches
- Components of a DIP system

What is an Image?

A two-dimensional function, f(x, y), where x and y are spatial (plane) coordinates, and the amplitude of f at any pair of coordinates (x, y) is called the intensity or gray level of the image at that point.

- 2D function
- Spatial coordinates
- Amplitude ↔ Intensity or gray level

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Digital Image

When *x*, *y*, and the amplitude values of *f* are all *finite, discrete* quantities, we call the image a digital image.

Digital Image Processing

The field of processing digital images by means of a digital computer.

Pixels

Finite elements which compose a digital image, with a particular location and value.

#picture-element #image-elements #pels

EM Vision

Imaging machines cover almost the entire EM spectrum, ranging from gamma to radio waves

A wide range of applications and enables numerous exciting possibilities

- **Digital Image Processing:**

  Concerns with the transformation of an image to a digital format & its processing by a computer or by dedicated H/W; both i/p & o/p are digital images

- **Digital Image Analysis:**

  Concerns with the description & recognition of the image contents – i/p is a digital image, the o/p is a symbolic description

- **Computer Vision:**

  Uses digital electronics to emulate human vision, including learning, making inferences, & taking actions

Several fields deal with images

Input/Output	Image	Description
Image	Image Processing	Computer Vision
Description	Computer Graphics	AI

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Principal application areas

1. Improvement of pictorial information for human interpretation
2. Processing of image data for storage, transmission, & representation for autonomous machine perception

- Eg: Categorize by image sources
  - Radiation from the Electromagnetic spectrum
  - Acoustic
  - Ultrasonic
  - Electronic (in the form of electron beams used in electron microscopy)
  - Computer (synthetic images used for modeling & visualization)

3 types of computerized processes

1. **Low**-level : Input & output are images
   - Primitive operations such as image preprocessing to reduce noise, contrast enhancement & image sharpening

1. **Mid**-level : Input may be images, output could be attributes extracted from those images
   - Segmentation
   - Description of objects
   - Classification of individual objects

1. **High**-level :
   - Image analysis

Fundamental steps in Digital Image Processing

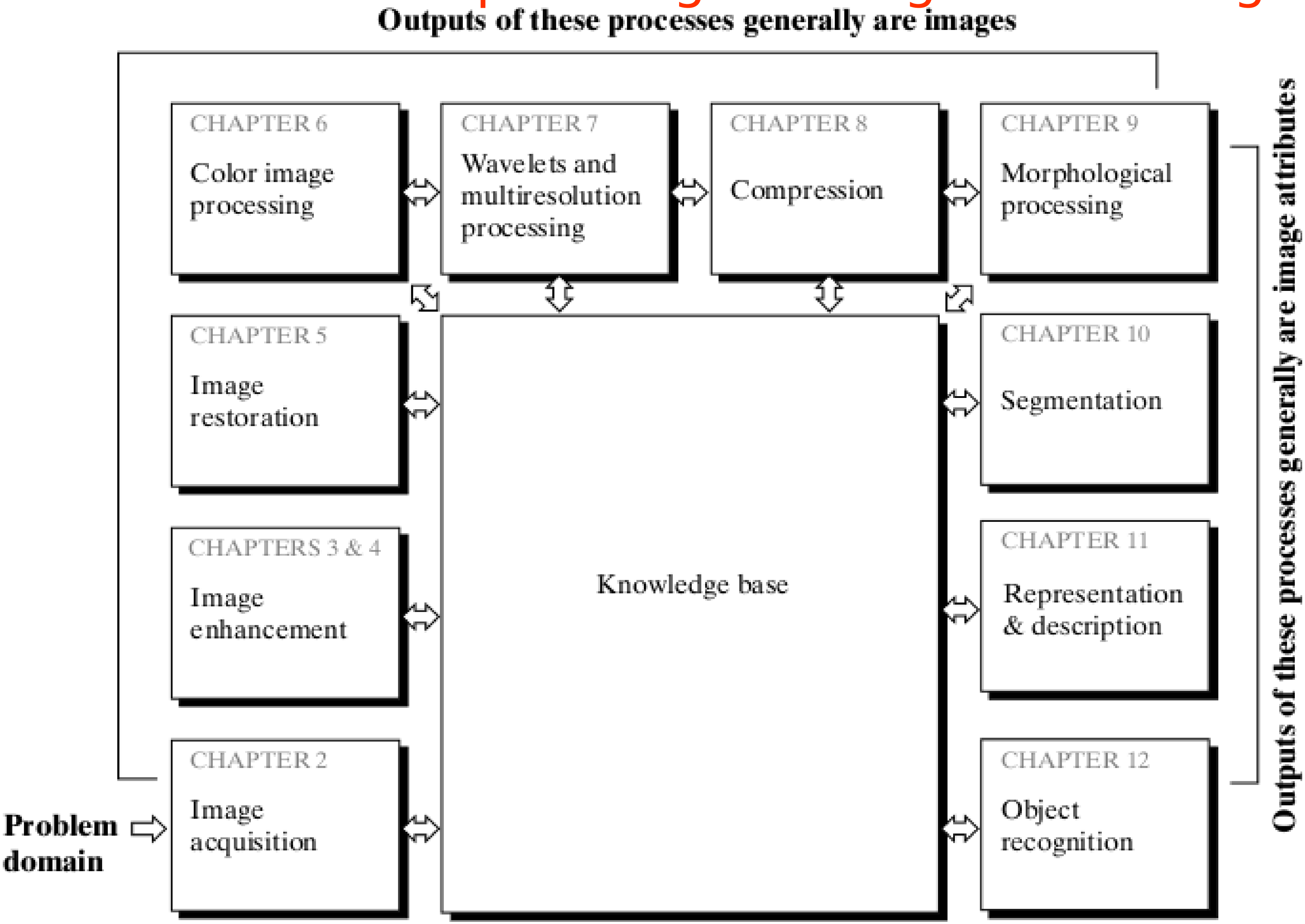

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Image Acquisition:

- An image is captured by a sensor (such as a monochrome or color TV camera) & digitized
- If the O/P of the camera or sensor is not already in digital form, an ADC converter digitizes it

Image Enhancement:

- To bring out detail that is obscured, or simply to highlight certain features of interest in an image

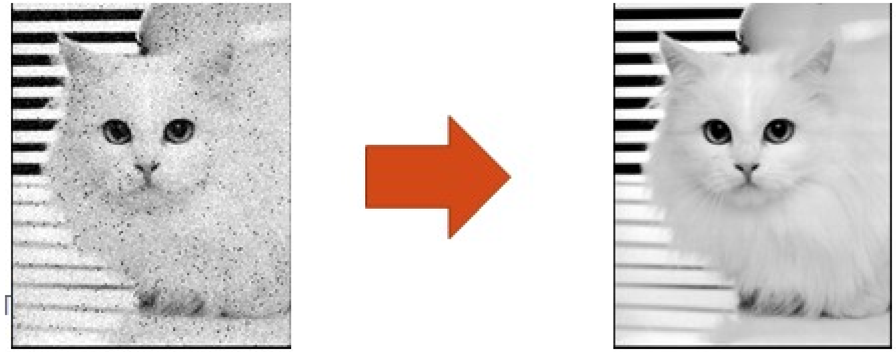

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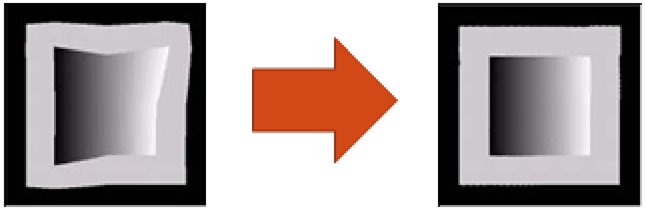
Image Restoration

- Improving the appearance of an image
- Tend to be based on mathematical or probabilistic models of image degradation



Colour Image Processing

- Gaining in importance because of the significant increase in the use of digital images over the Internet

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Wavelets

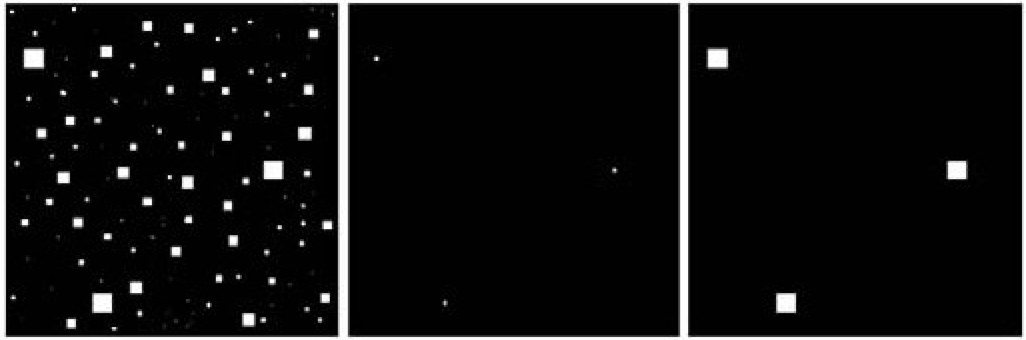
- Foundation for representing images in various degrees of resolution
- Used in image data compression & pyramidal representation (images are subdivided successively into smaller Regions)

Compression

- Reducing the storage space required to save an image or the BW required to transmit it
- Ex. JPEG (Joint Photographic Experts Group) image compression standard

Morphological processing

- Deals with Tools for extracting image components that are useful in the representation & description of shape



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Segmentation

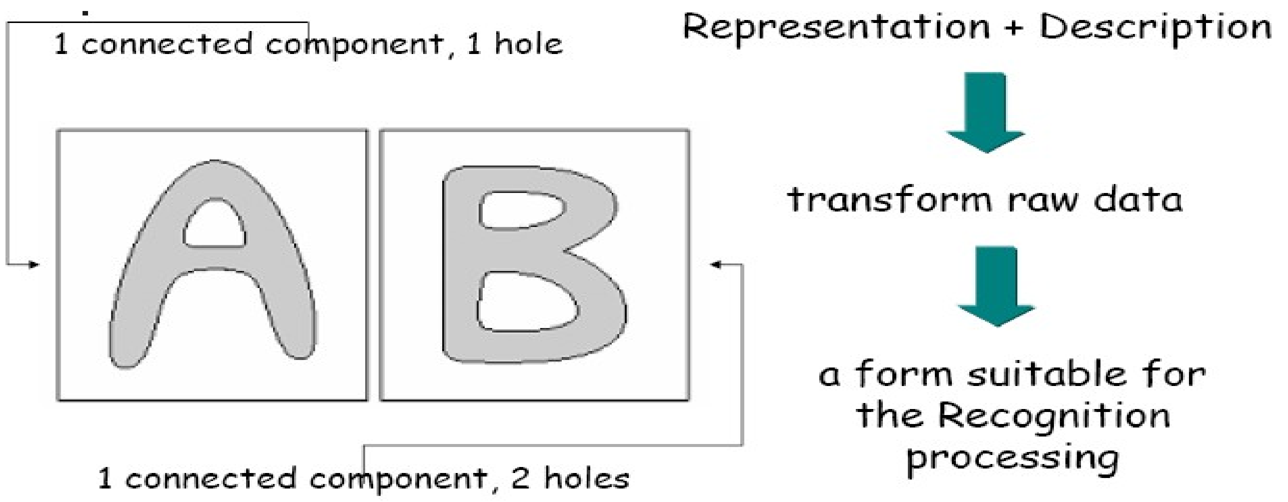
- Partitions an image into its constituent parts or objects
- Autonomous segmentation is one of the most difficult tasks in DIP
- A rugged segmentation procedure brings the process a long way toward successful solution of imaging problems that require objects to be identified individually
- O/P of the segmentation stage is raw pixel data, constituting either the boundary of a region or all the points in the region itself

Representation & Description

- Converts the raw data from segmentation to a form suitable for computer processing
- Representation → make a decision whether the data should be represented as a boundary or as a complete region

1. Boundary representation → focus on external shape characteristics, such as corners & inflections
2. Region representation → focus on internal properties, such as texture or skeleton shape

- Description(feature selection), deals with extracting attributes



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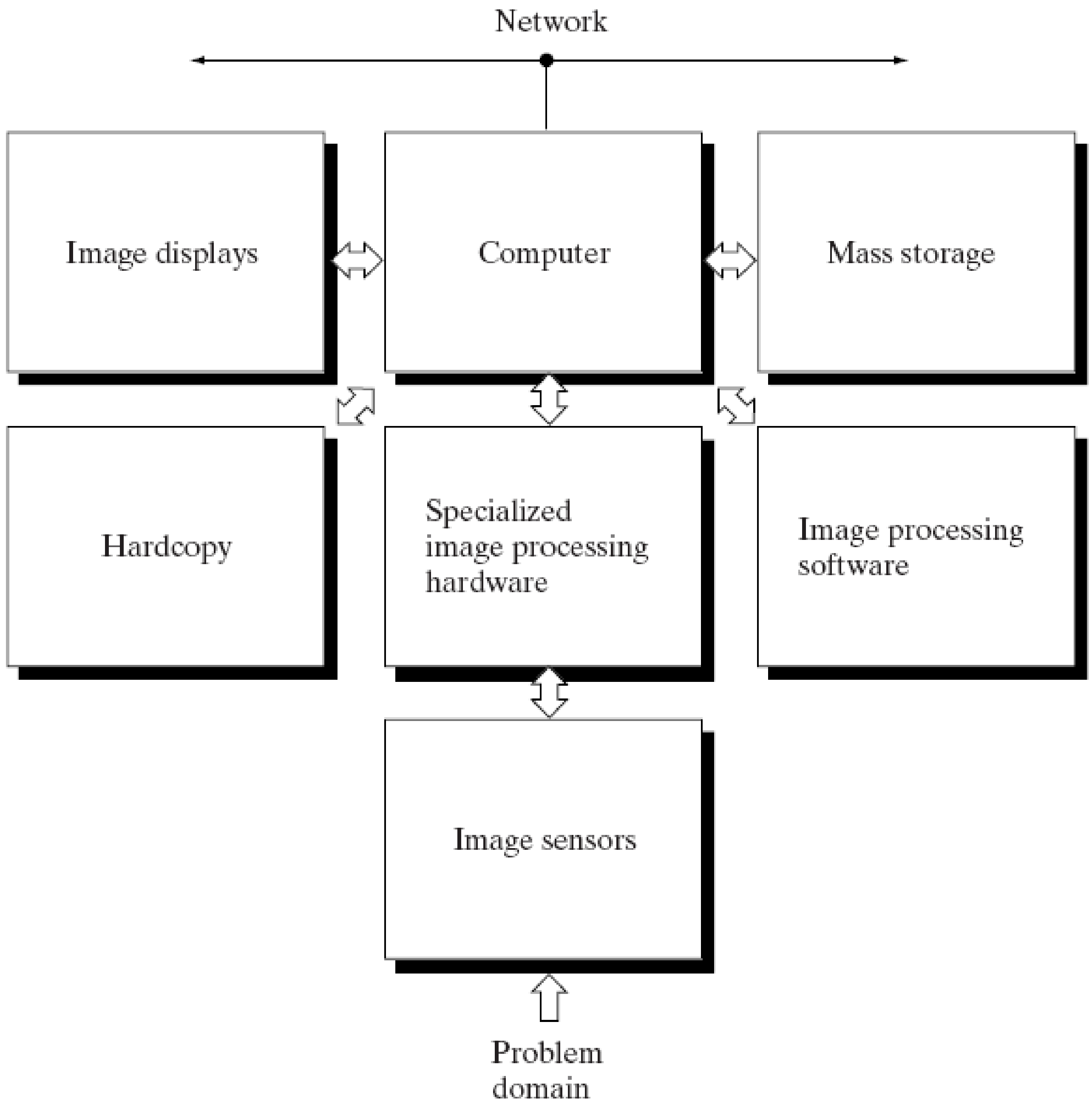
Recognition & Interpretation

- Recognition → the process that assigns a label to an object based on the information provided by its descriptors
- Interpretation → assigning meaning to an ensemble of recognized objects

Knowledge Base

- A problem domain detailing regions of an image where the information of interest is known to be located
- Help to limit the search

COMPONENTS OF A GENERAL-PURPOSE IMAGE PROCESSING SYSTEM :



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- ***Image acquisition:*** This is carried out by sensors. Sensing involves 2 elements, namely
  - **Physical device** that is sensitive to the energy radiated by the object we wish to image
  - **Digitizer** that converts the o/p of the physical sensing device into digital form

- ***Specialized image processing hardware*** consists of a digitizer & an ALU used for performing arithmetic or logical operations on the image.
  Also called *front-end subsystem : Speed!*

- ***Computer*** is used for performing off line image processing tasks. Computer can range from a general PC to a super computer

- ***Software*** for image processing consists of specialized modules that perform specific tasks on the image, with *options for users to write code.*

- ***Software*** for image processing consists of specialized modules that perform specific tasks on the image

  A well-designed package also includes the capability for the user to write code that, as a minimum,

  Sophisticated software packages allow the integration of those modules and general-purpose software commands from at least one computer language.

- **Mass Storage** is essential in image processing applications

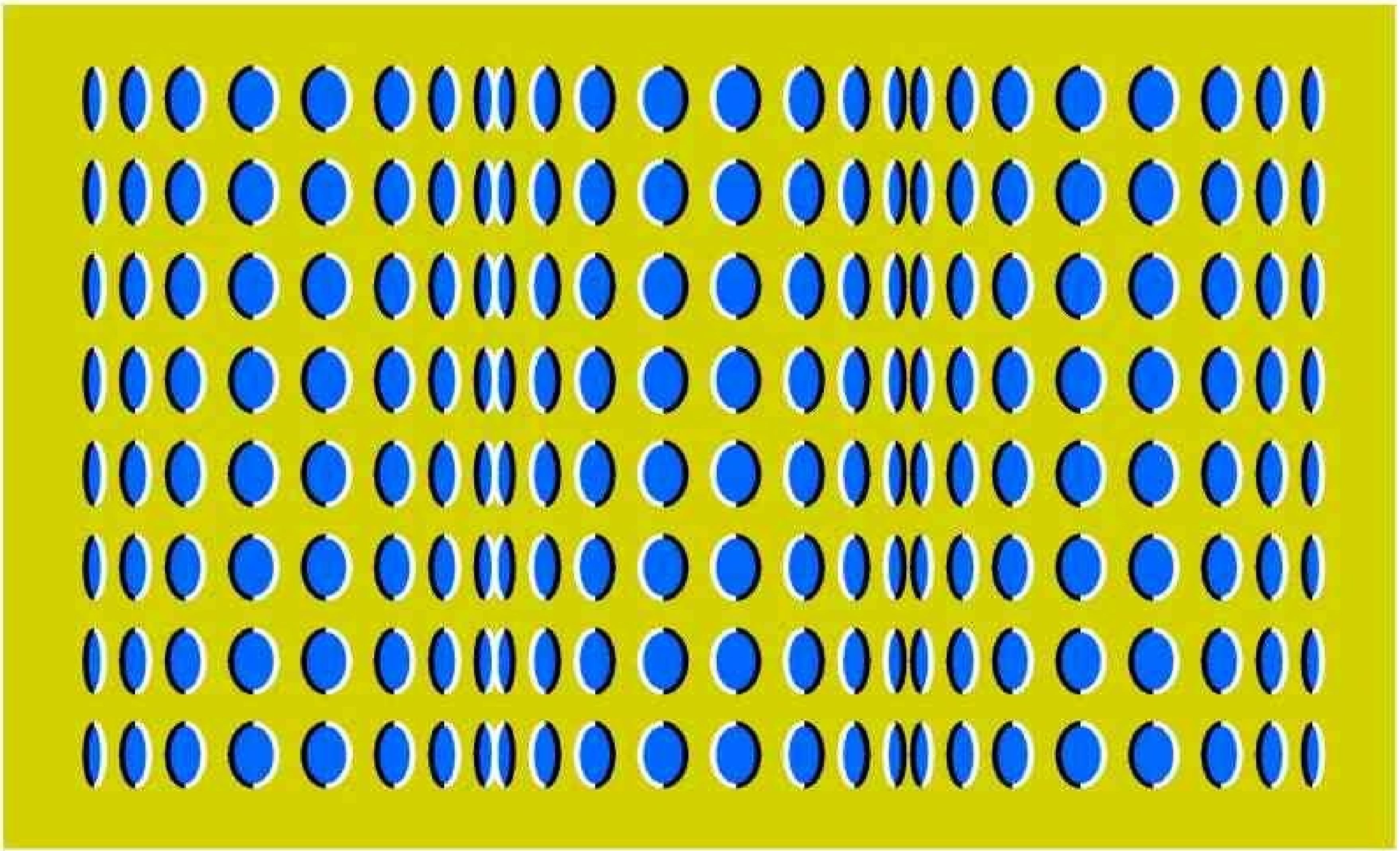
  Short Term Storage: required during processing. Frame Buffers that can store 1 or 2 images at a time & allows image zooming, scrolling & panning are used
  On Line Storage: for fast recall. Magnetic disks or optical media storage is used
  Archival Storage: for infrequent access. Magnetic tapes & optical disks are used

- **Image Displays** consists of *monitors;* they are driven by o/ps of image & graphic display cards. Sometimes *stereo displays*

- **Hardcopy** devices for recording images include laser printers, film cameras, heat sensitive devices, inkjet units and digital units such as optical & CDROM disks

- **Networking** is vital function, because it is necessary to transmit images. During transmission BW is the key factor to be considered
  Situation getting better with OFC and broadband communications

Elements of Visual Perception



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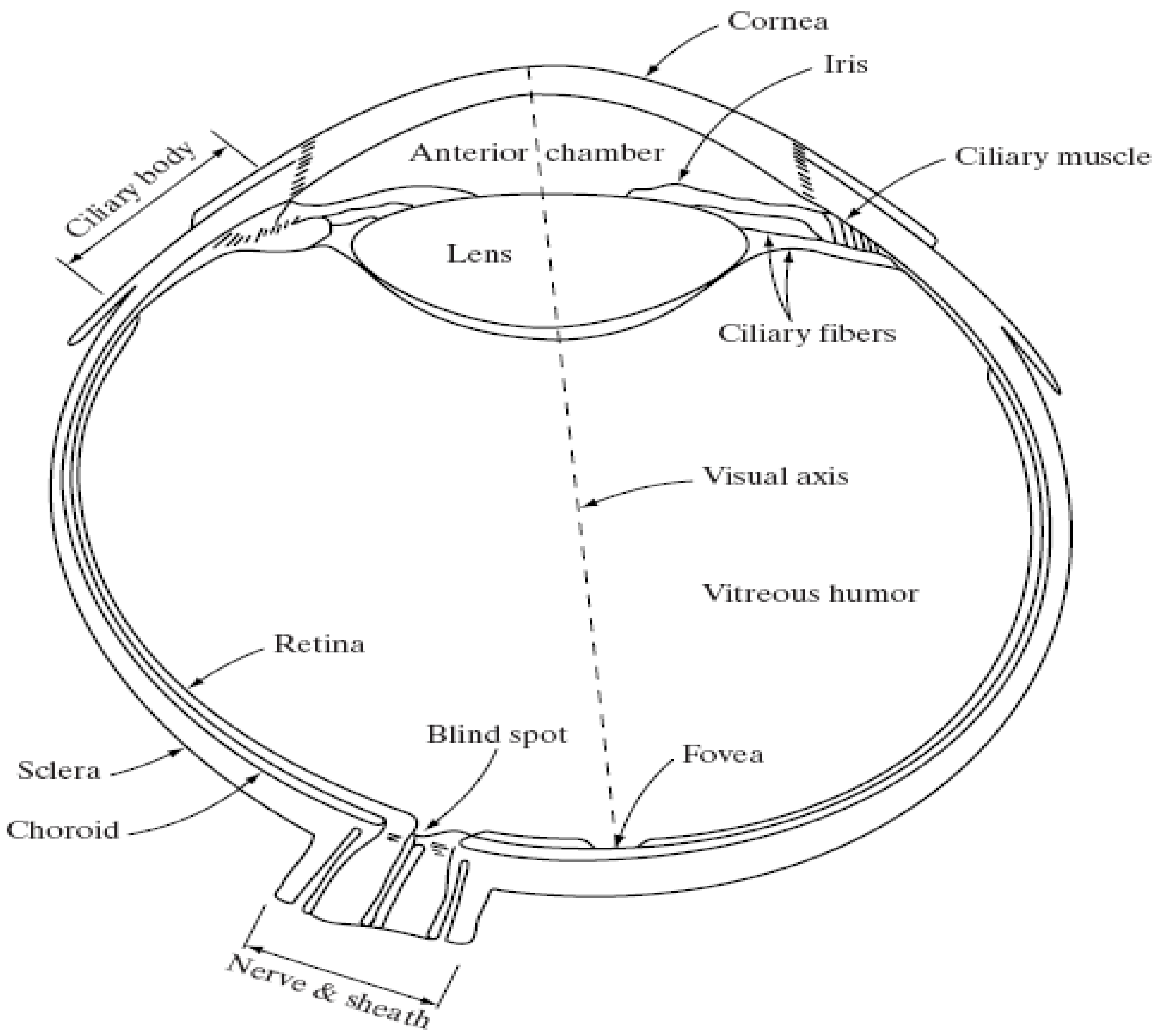
Human perception vs Mathematical assertion

- DIP is built on a foundation of mathematical and probabilistic formulations
- Nonetheless, human intuition and analysis play a central role in the choice of one technique versus another
- It is ultimately based on subjective, visual judgments

Some rudimentary aspects of human vision

- Mechanics and parameters related to how images are formed in the eye
- Physical limitations of human vision
- Comparing human and electronic imaging in terms of resolution and ability to adapt to changes

Structure of the Human Eye



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Structure of human eye

- It is nearly a sphere, with an average diameter of approximately 20 mm.
- Three membranes enclose the eye: **the cornea** and **sclera** outer cover; the **choroid** and the the **retina**.

Cornea and Sclera:

- Cornea is a tough, transparent tissue that covers the anterior surface of the eye
- Continuous with the cornea, the sclera is an opaque membrane that encloses the remainder of the optic globe

Choroid:

- The choroid lies directly below the sclera.
- This membrane contains a network of blood vessels that serve as the major source of nutrition to the eye.
- Choroid coat is heavily pigmented, and hence helps to reduce the amount of *extraneous light* entering the eye and the *backscatter* within the optical globe.
- Anterior extreme of the choroid is divided into the *ciliary body* and the *iris diaphragm.*
- Iris diaphragm contracts or expands to control the amount of light that enters the eye

Iris

- The central opening of the iris (the pupil) varies in diameter from approximately 2 to 8 mm.
- The front of the iris contains the visible pigment of the eye, whereas the back contains a black pigment.

Lens

Made up of concentric layers of fibrous cells and is suspended by fibers that attach to the ciliary body

- Contains 60 to 70% water, about 6% fat, and more protein than any other tissue in the eye.
- Colored by a slightly yellow pigmentation that increases with age
- Absorbs approximately 8% of the visible light spectrum, with relatively higher absorption at shorter wavelengths

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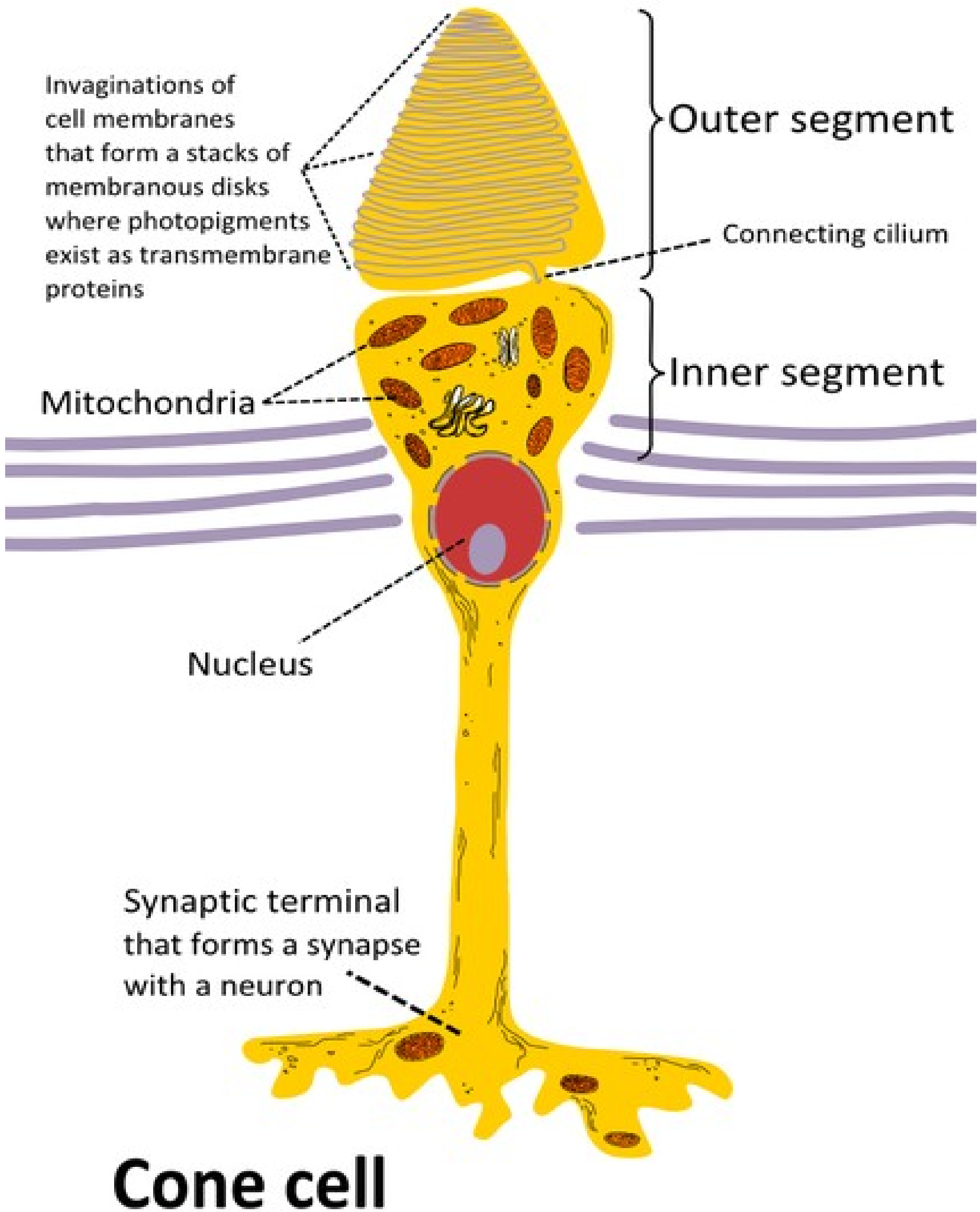
Retina

Lines the inside of the wall's entire posterior portion.

- When the eye is properly focused, light from an object outside the eye is imaged on the retina
- Pattern vision is afforded by the distribution of *discrete light receptors* over the surface of the retina
- There are two classes of receptors: ***cones*** and ***rods***.



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Cone Cells

The cones in each eye number between 6 and 7 million.

- They are located primarily in the central portion of the retina, called the fovea, and are highly sensitive to color
- Humans can resolve fine details with these cones largely because each one is connected to its own nerve end.
- Muscles controlling the eye rotate the eyeball until the image of an object of interest falls on the fovea.
- Cone vision is called *photopic* or *bright-light vision*.

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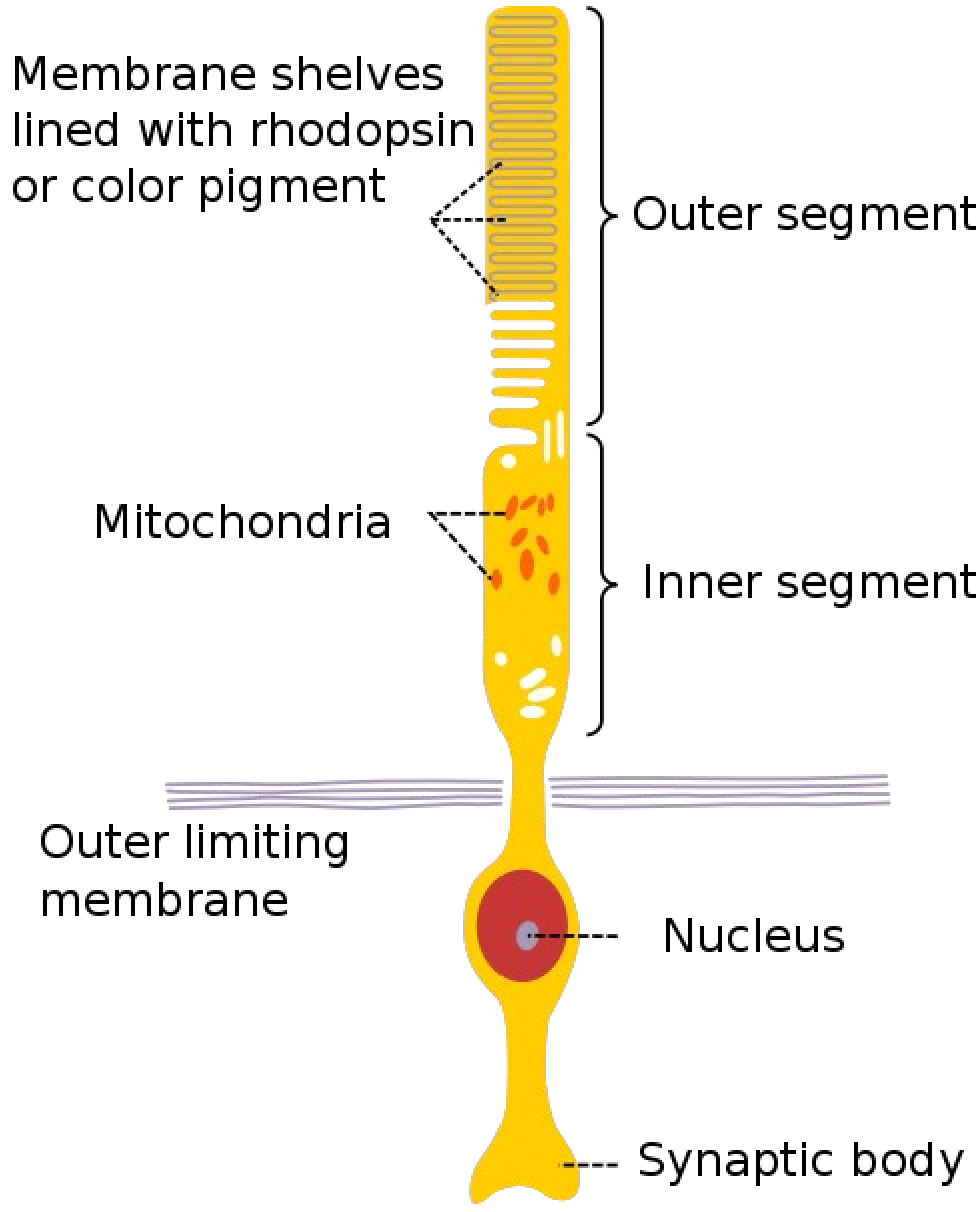
Rod Cells



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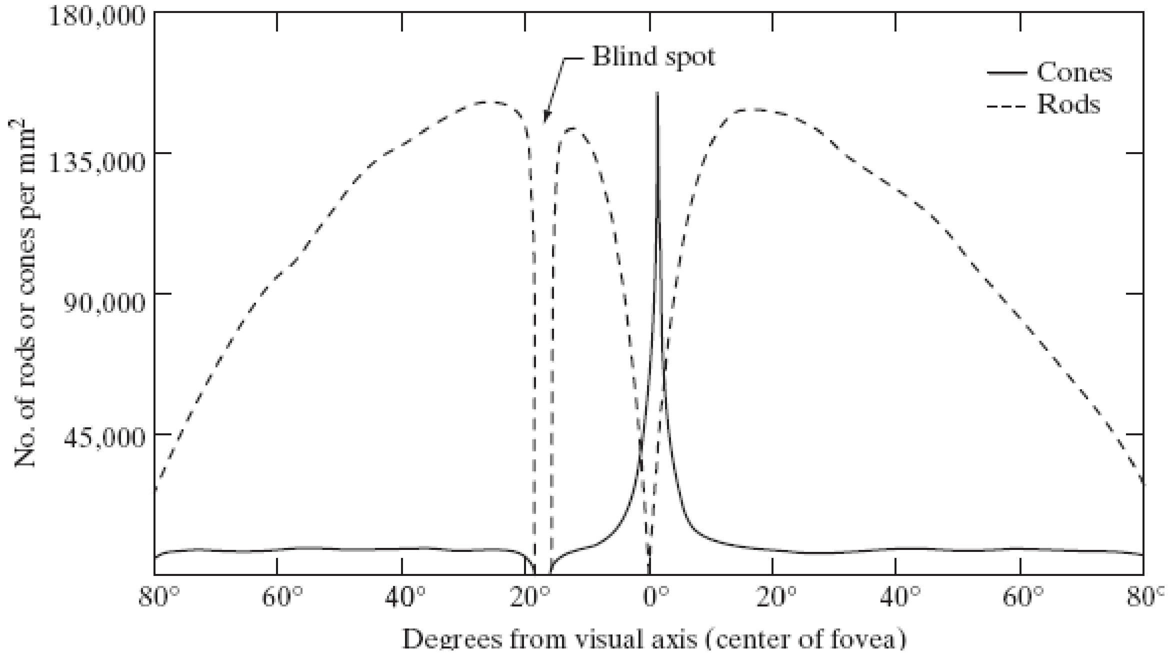
Rod Cells

Some 75 to 150 million are distributed over the retinal surface.

- Several rods are connected to a single nerve end reduce the amount of detail discernible by these receptors.
- Give a general, overall picture of the field of view.
- They are not involved in color vision and are sensitive to low levels of illumination.
- *Scotopic* or *dim-light vision*

Cross section of the right eye



- Blind spot → the absence of receptors area
- Receptor density is measured in degrees from the fovea
- Cones are most dense in the center of the retina (in the area of the fovea)
- Rods increase in density from the center out to approx. 20° off axis & then decrease in density out to the extreme periphery of the retina

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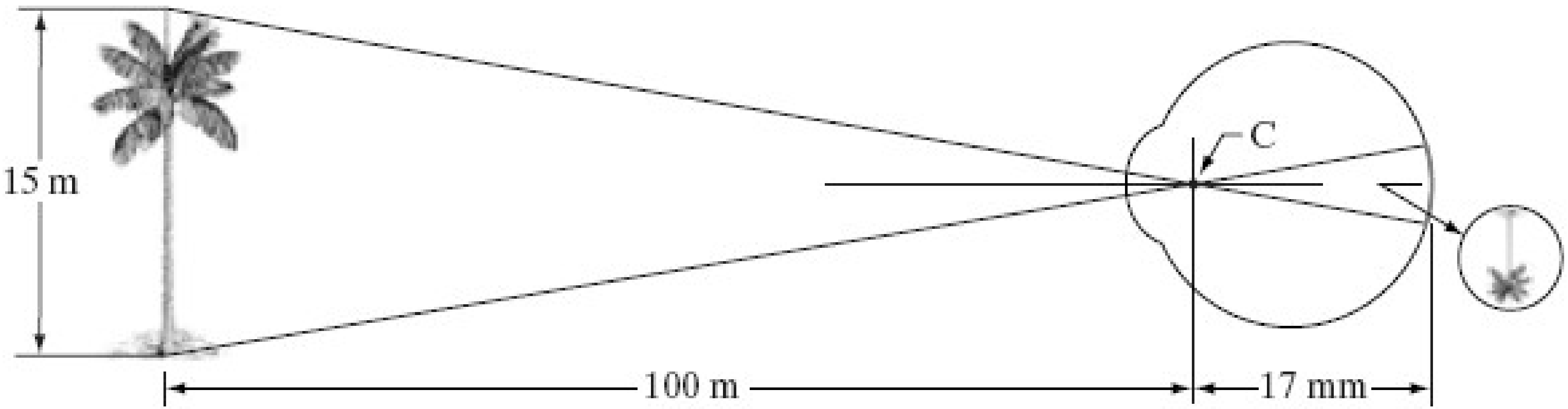
Comparison of raw resolving power b/w human eye and a CCD sensor camera

- Fovea as a square sensor array of size 1.5 mm*1.5 mm ->150,000 elements per mm^2
- Cones in the region of highest acuity in the eye is about 337,000 elements <-> no larger than 5 mm*5 mm CCD sensor

Image Formation in the Eye



- Principal difference b/w the **lens of the eye** & an ordinary optical lens is that the former is **flexible**
- Radius of curvature → the anterior surface > its posterior surface
- Shape→ is controlled by tension in the fibers of the ciliary body
- Focus
  - On **distant** objects, the controlling muscles cause the lens to be relatively **flattened**
  - these muscles allow the lens to become **thicker** in order to focus on objects **near** the eye

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- When the eye focuses on an object **farther** away than about 3m, the lens exhibits its **lowest** refractive power

- When the eye focuses on a **nearby** object, the lens is most **strongly** refractive

- This information makes it easy to calculate the size of the retinal image of any object

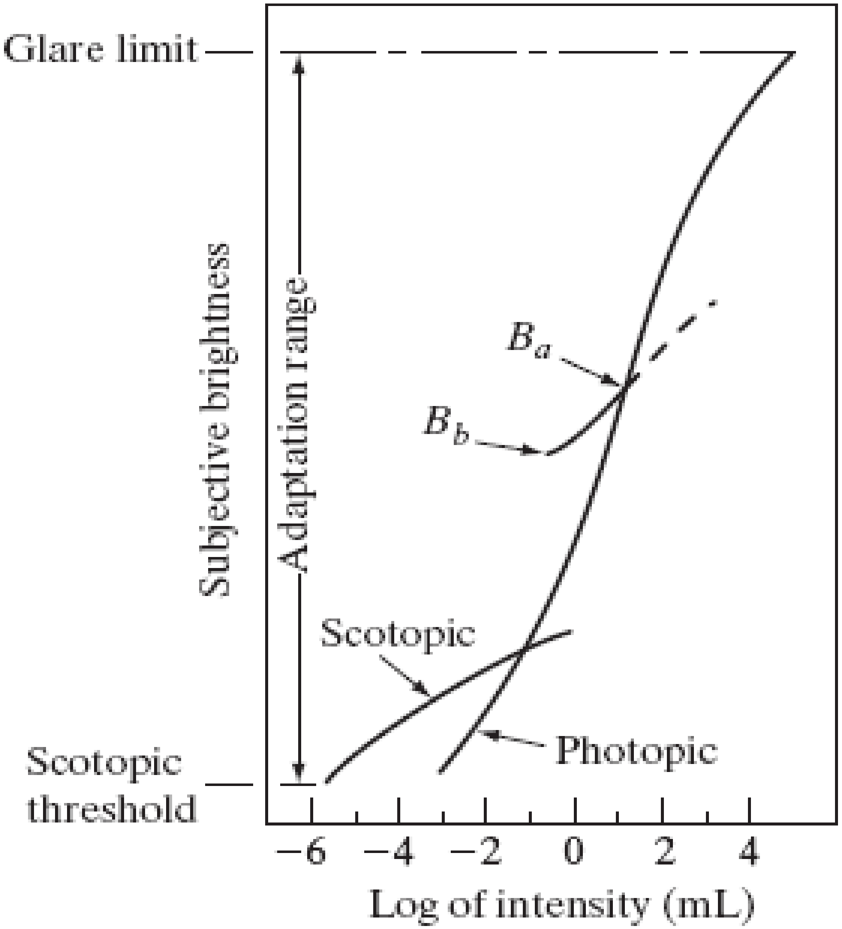
- 15/100=h/17 or h=2.55 mm

Brightness adaptation & discrimination

- The eye can adapt to an enormous range (in the order of 10^10) of light intensity, from **scotopic** threshold to the glare limit

- Subjective brightness (i.e. perceived intensity) is a log function of the light intensity incident on the eye

- In **photopic** vision alone, the range is about 10^6



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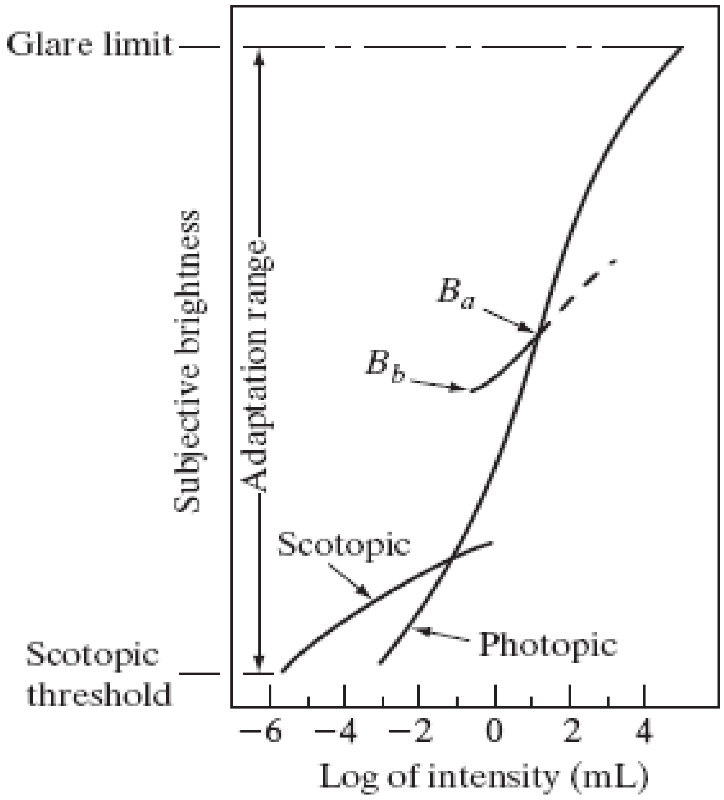
- **Brightness adaptation :** Visual system cannot operate over such a huge range *simultaneously*; instead, it changes its *overall sensitivity*
- E.g.: if the eye is adapted to brightness level B_a, the short intersecting curve represents the range of subjective brightness perceived by the eye. The range is rather restricted, i.e. below level B_b all stimuli are perceived as black
- The upper part of the curve (dashed) is not restricted, but when extended too far it looses its meaning as it raises the adaptation level higher than B_a



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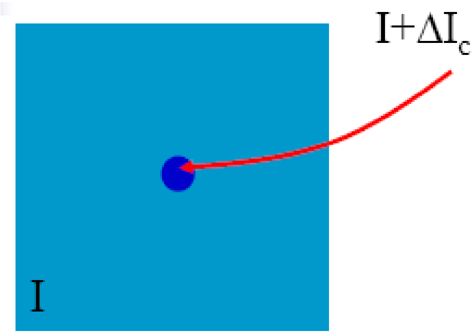
Weber ratio: Contrast sensitivity

Experiment for Brightness discrimination



Weber's ratio: $\Delta I_c / I$

- Ability of the eye to discriminate b/w changes in brightness at any specific adaptation level
- Look at a flat, uniformly illuminated large area, e.g. a large opaque glass illuminated from behind by a light source with intensity I
- Add an increment of illumination ΔIc, in the form of a short duration flash as a circle in the middle. Vary ΔIc & observe the result. The results should move from ”no perceivable change” to ”perceived change”.

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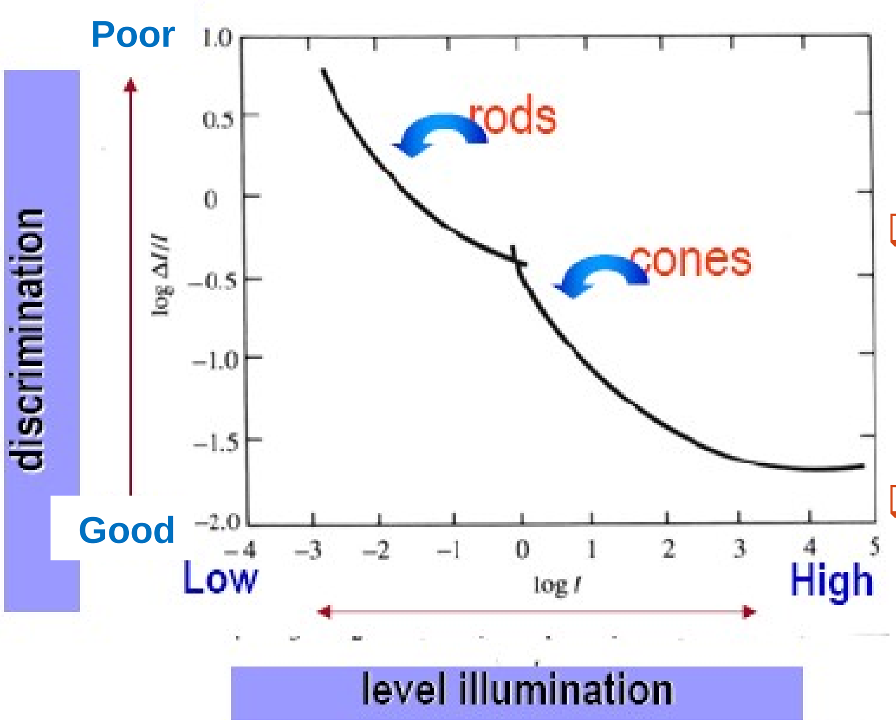
Weber Ratio: Contrast Sensitivity

- The quantity ΔI_c, where ΔI_c is the increment of illumination discriminable 50% of the time with background illumination I, is called the Weber ratio

Good brightness discrimination → $\Delta I_c/I$ is small
Bad brightness discrimination → $\Delta I_c/I$ is large

Contd...



- Brightness discrimination is poor (the Weber ratio is large) at low levels of illumination & improves significantly (the ratio decreases) as background illumination increases
- It is difficult to distinguish the discrimination when it is bright area but easier when the discrimination is on a dark area
- 2 branches illustrate the fact that at low levels of illumination vision is carried out by the rods, whereas at high levels, cones are at work

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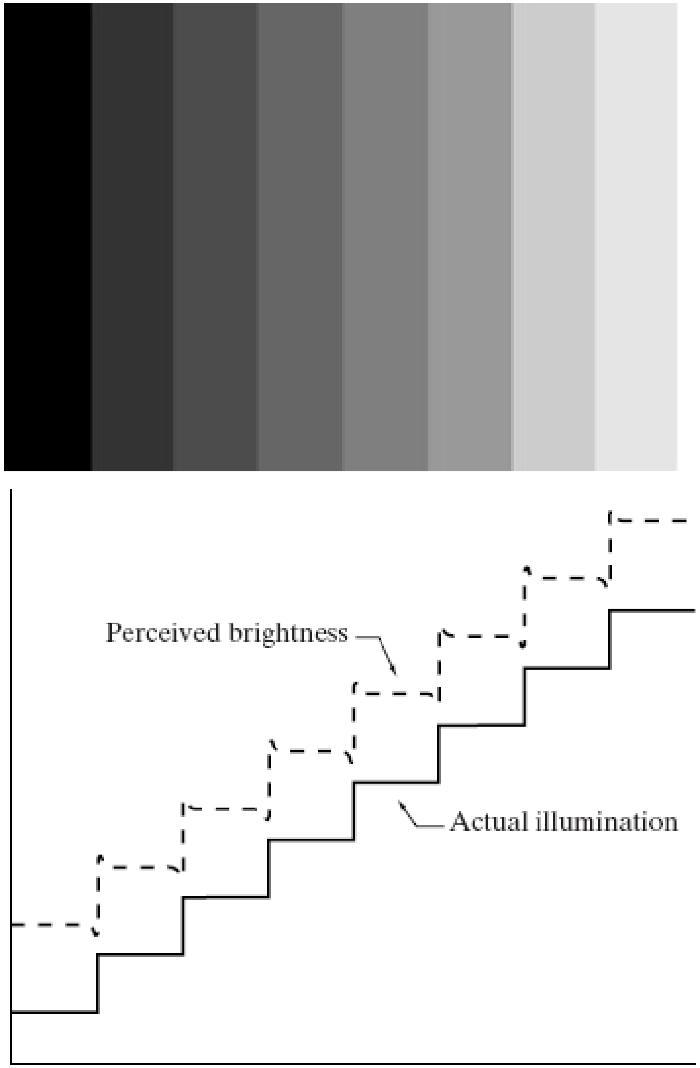
Brightness VS Function of intensity



- Brightness is not a simple function of intensity
- Visual system tends to undershoot or overshoot around the boundary of regions of different intensities
- The intensity of the stripes is constant but we actually perceive a brightness pattern is strongly scalloped near the boundaries

Mach band pattern

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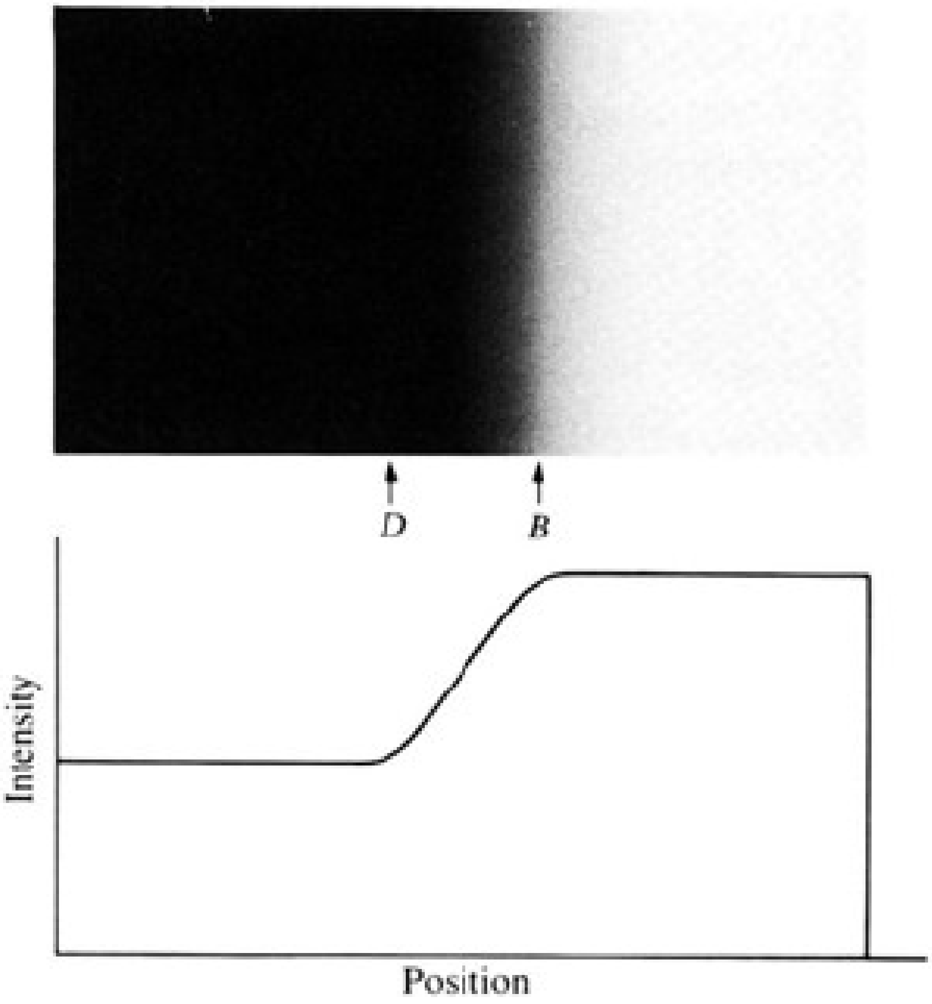
Contd…

Is it the same level of darkness around area D & B ?



- Brightness pattern perceived is a darker stripe in region D & a brighter one in the region B whereas actually the region from D to B has the same intensity

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Simultaneous contrast

Which small square is the darkest one ?

- All the small squares have exactly the same intensity, but they appear to the eye progressively darker as the background becomes brighter

- Region's perceived brightness does not depend simply on its intensity

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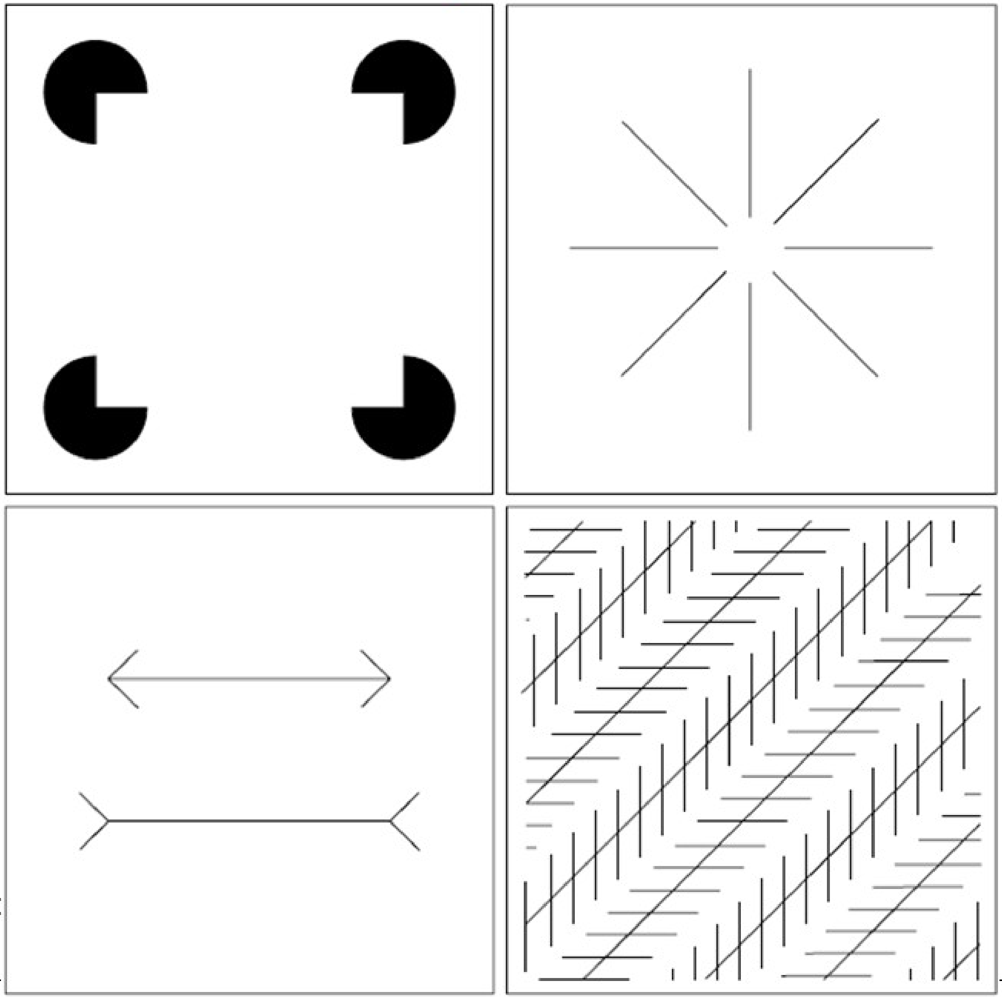
Human Perception Phenomena



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Referneces :

“Digital Image Processing”, Rafael C.Gonzalez and Richard E. Woods, Pearson Education, 2001, 2nd edition.

Wikipedia of course!